CHAPTER 2

FORECASTING UPPER AIR SYSTEMS

To prepare surface and upper air prognostic charts, we must first make predictions of the weather systems for these charts. Inasmuch as the current surface and upper air charts reveal the current state of the weather, so should the prognostic charts accurately reveal the future state of the weather.

Preparing upper air and surface prognostic charts dictates that the Aerographer's Mate first begin with the upper levels and then translate the prognosis downward to the surface. The two are so interrelated that consideration of the elements on one should not be made independently of the other.

Prognostic charts are constructed at the Fleet Numerical Meteorology and Oceanography Center (FNMOC). The resultant products are transmitted over their respective facsimile networks.

Overseas Meteorology and Oceanography (METOC) units also construct and transmit prognostic charts. We are all too often inclined to take these products at face value. Since these prognostic charts are generally for large areas, this practice could lead to an erroneous forecast.

It is important that you, the Aerographer's Mate, not only understand the methods by which prognostic charts are constructed, but you should also understand their limitations as well. In this chapter we will discuss some of the more common methods and rules for forecasting upper air features. In the following chapter, methods and techniques for progging upper air charts will be considered. These methods can be used in constructing your own prognostic charts where data are not available and/or to check on the prognostic charts made by other sources.

Before you read this chapter, you may find it beneficial to review the *AG2* TRAMAN, NAVEDTRA 10370, volume 1, unit 8, which discusses upper air analysis concepts.

GENERAL PROGNOSTIC CONSIDERATIONS

LEARNING OBJECTIVES: Evaluate features on upper level charts, and be familiar with the various meteorological products available to the forecaster in preparing upper level prognostic charts.

The forecaster must consider all applicable forecasting rules, draw upon experience, and consult all available objective aids to produce the best possible forecast from available data.

Forecasters should examine all aspects of the weather picture from both the surface and aloft before issuing their forecasts. Some conditions are deemed less important, while others are emphasized. Forecasters must depend heavily upon their knowledge and experience as similar conditions yield similar consequences. Some forecasters may decide to discard a parameter, such as surface pressure, because through their experience, or the experience of others, they may decide that it is not a decisive factor.

An objective system of forecasting certain atmospheric parameters may often exceed the skill of an experienced forecaster. However, the objective process should not necessarily y take precedence over a subjective method, but rather the two should be used together to arrive at the most accurate forecast.

HAND DRAWN ANALYSIS

Methods and procedures used in the analysis of upper air charts were covered in the *AG2* TRAMAN, volume 1. Accurately drawn analyses provide the forecaster with the most important tool in constructing an upper air prognostic chart. Such information as windspeed and direction, temperature, dew point depression, and heights are readily available for the forecaster to integrate into any objective method for producing a prognostic chart.

COMPUTER PRODUCTS

FNMOC provides a large number of charts for dissemination to shore and fleet units. These include analysis and prognostic charts ranging from subsurface oceanographic charts to depictions of the troposphere, as well as a number of specialized charts. A complete listing of the these charts is contained in The *Numerical Environmental Products Manual,* volume III *(Environmental Products),* FLENUMMETOCCENINST 3145.2.

APPLICATION OF SATELLITE IMAGERY

As a further aid, satellite imagery can also be used in preparing prognostic charts. The availability of useful satellite data will vary with time and area.

OBJECTIVE FORECASTING TECHNIQUES

LEARNING OBJECTIVES: Evaluate various objective forecasting techniques, including extrapolation and isotherm-contour relationships for the movement of troughs and ridges. Forecast intensity of troughs and ridges. Forecast the movement of upper level features. Forecast the intensity of upper level and associated surface features. Lastly, forecast the formation of upper level and associated surface features.

Experience in itself is not always enough to forecast the movement and/or intensity of upper air systems, but, couple the forecasters experience with basic objective techniques and a more accurate product will be prepared.

FORECASTING THE MOVEMENT OF TROUGHS AND RIDGES

Techniques covered in this section apply primarily to long waves. Some of the techniques will be applicable to short waves as well. A long wave is by definition a wave in the major belt of westerlies, which is characterized by large length and significant amplitude. (See the *AG2* TRAMAN, volume 1, for a discussion of long and short waves.) Therefore, the first step in progging the movement and intensity of long waves is to determine their limits. There are several basic approaches to the progging of both long and short waves. Chiefly, these are extrapolation, isotherm-contour relationship, and the location of the jet maximum in relation to the current in which it lies.

Extrapolation

The past history of systems affecting an area of interest is *fundamental* to the success of forecasting. Atmospheric systems usually change slowly, but, continuously with time. That is, there is continuity in the weather patterns on a sequence of weather charts. When a particular pressure system or height center exhibits a tendency to continue without much change, it is said to be *persistent.* These concepts of persistence and continuity are *fundamental* forecast aids.

The extrapolation procedures used in forecasting may vary from simple extrapolation to the use of more complex mathematical equations and analog methods based on theory. The forecaster should extrapolate past and present conditions to obtain future conditions. Extrapolation is the simplest method of forecasting both long and short wave movement.

Simple extrapolation is merely the movement of the trough or ridge to a future position based on past and current movement and expected trends. It is based on the assumption that the changes in speed of movement and intensity are slow and gradual. However, it should be noted that developments frequently occur that are not revealed from present or past indications. However, if such developments can be forecast by other techniques, allowances can be made.

Extrapolation for short periods on short waves is generally valid. The major disadvantage of extrapolating the long period movement of short waves or long waves is that past and present trends do not continue indefinitely. This can be seen when we consider a wave with a history of retrogression. The retrogression will not continue indefinitely, and we must look for indications of its reversal; that is, progressive movement.

Isotherm-Contour Relationships

The forecaster should always examine the long waves for the isotherm-contour relationships, and then apply the rules for the movement of long waves. These rules are covered in the *AG2* TRAMAN, volume 1. These rules are indicators only, but if they confirm or parallel other applied techniques, they have served their purpose. A number of observations and rules are stated regarding the progression, stationary characteristics, or retrogression of long waves. These rules are discussed in the following text.

PROGRESSION OF LONG WAVES.— Progression (eastward movement) of long waves is usually found in association with relatively short wave lengths and well defined major troughs and ridges. At the surface, there are usually only one or two prominent cyclones associated with each major trough aloft. Beneath the forward portion of each major ridge there is usually a well developed surface anticyclone moving toward the east or southeast. The 24-hour height changes at upper levels usually have a one-to-one association with major troughs and ridges; that is, motion of maximum height fall and rise areas associated with major trough and ridge motion. The tracks of the height change centers depend on the movement and changes in intensity of the long waves.

STATIONARY LONG WAVE PATTERNS.— Once established, stationary long wave patterns usually persist for a number of days. The upper airflow associated with the long wave pattern constitutes a steering pattern for the smaller scale disturbances *(short waves).* These short waves, with their associated height change patterns and weak surface systems, move along in the flow of the large scale, long wave pattern. Short wave troughs deepen as they move through the troughs of the long waves, and fill as they move through the ridges of the long waves. The same changes in intensity occur in sea level troughs or pressure centers that are associated with minor troughs aloft. Partly as a result of the presence of these smaller scale systems, the troughs and ridges of the stationary long waves are often spread out and hard to locate exactly.

RETROGRESSION OF LONG WAVES.— A continuous retrogression of long wave troughs is a rare event. The usual type of retrogression takes place in a discontinuous manner; a major trough weakens, accelerates eastward, and becomes a minor trough, while a major wave trough forms to the west of the former position of the old long wave trough. New major troughs are generally formed by the deepening of minor troughs into deep, cold troughs.

Retrogression is seldom a localized phenomenon, but appears to occur as a series of retrogressions in several long waves. Retrogression generally begins in a quasi-stationary long wave train when the stationary wavelength shows a significant decrease. This can happen as a result of a decrease in zonal wind speed, or of a southward shift in the zonal westerlies. Some characteristics of retrogression are as follows:

- Trajectories of 24-hour height change patterns at 500-hPa deviate from the band of maximum wind.
- New centers appear, or existing ones rapidly increase in intensity.
- Rapid intensification of surface cyclones occurs to the west of existing major trough positions.

Location Of The Jet Stream

The *AG2* TRAMAN, volume 1, discusses the migration of the jet stream both northward and southward. Some general considerations can be made concerning this migration and the movement of waves in the troposphere:

- In a northward migrating jet stream, a west wind maximum emerges from the tropics and gradually moves through the lower midlatitudes. Another maximum, initially located in the upper midlatitudes, advances toward the Arctic Circle while weakening. Open progressive wave patterns with pronounced amplitude and a decrease in the number of waves due to cutoff centers exist. The jet is well organized and troughs extend into low latitudes.
- As the jet progresses northward, the amplitude of the long waves decrease and the cutoff lows south of the westerlies dissipate. By the time the jet reaches the midlatitudes, a classical *high zonal index (AG2* TRAMAN, volume 1) situation exists. Too, we have weak, long waves of large wavelength and small amplitude, slowly progressive or stationary. Few extensions of troughs into the low latitudes are present, and in this situation, the jet stream is weak and disorganized.
- As the jet proceeds farther northward, there will often be a sharp break of high zonal index with rapidly increasing wave amplitudes aloft. Long waves retrograde. As the jet reaches the upper midlatitudes and into the sub-Arctic region, it is still the dominant feature, while a new jet of the westerlies gradually begins to form in the subtropical regions. Long waves now begin to increase in number, and there is a reappearance of troughs in the tropics. The cycle then begins again.

With a southward migrating jet, the processes are reversed from that of the northward moving jet. It should be noted that shortwaves are associated with the jet maximum and move with about the same speed as these jet maximums.

FORECASTING THE INTENSITY OF TROUGHS AND RIDGES

Forecasting the intensity of long wave troughs and ridges often yields nothing more than an indication of the expected intensity; that is, greater than or less than present intensity. For instance, if deepening or falling is indicated, but the extent of deepening or tilling is not definite, the forecaster is forced to rely on experience and intuition in order to arrive at the amount of deepening or tilling. FNMOC upper level charts forecast the intensity of upper waves with a great deal of success. If available, you should check your intensity and movement predictions against these prognoses.

Extrapolation

Patterns on upper level charts are more persistent than those on the surface. Therefore, extrapolation gives better results on the upper air charts than on surface charts. When you use height changes aloft, the procedure is to extrapolate height change and add or subtract the change to the current height values.

Use of Time Differentials

The time differential chart is discussed in the *AG2* TRAMAN, volume 1.

The time differential chart constructed for the 500-hPa level shows the history of changes that have taken place at the 500-hPa level at 24-hour intervals. In considering the information on the time differential chart, those centers with a well defined history of movement will be of greatest value. Take into consideration not only the amount of movement, but also the changes in intensity of the centers. Centers with no history should be treated with caution, especially with regard to their direction of movement which is usually downstream from the current position. Information derived from the time differential chart should be used to supplement information obtained from previous considerations, and when in agreement, used as a guide for the amount of change.

Normally, the 24-hour height rise areas can be moved with the speed of the associated short wave ridges, and the speed of the fall centers with the speed of the associated short wave troughs. It must be remembered that height change centers may be present due to convergence or divergence factors and may not have an associated short wave trough or ridge. Be cautious not to move a height change center with the contour flow if it is due primarily to convergence or divergence. However, with short wave indications, a change center will appear and move in the direction of the contour flow.

Once you have progged the movement of the height change centers and determined their magnitude, apply the change indicated to the height on the current 500-mb chart. You should use these points as guides in constructing prognostic contours.

Isotherm-Contour Relationship

In long waves, deepening of troughs is associated with cold air advection on the west side of the trough and filling of troughs with warm air advection on the west side of the trough. The converse is true for ridges. Warm air advection on the western side of a ridge indicates intensification, and cold air advection indicates weakening. This rule is least applicable immediate yeast of the Continental Divide in the United States, and probably east of any high mountain range where westerly winds prevail aloft. In short waves, deepening of troughs is associated with cold air advection on the west side of the trough and falling of troughs with warm air advection, particularly if a jet maximum is in the northerly current of the trough and tilling is indicated by warm air advection on the western side.

In reference to the above paragraph, the advection is not the cause of the intensity changes, but rather is a "sign" of what is occurring. High level convergence/divergence is the cause.

Effect of Super Gradient Winds

Figure 2-1, views (A) through (D), shows the effect of the location of maximum winds on the intensity of troughs and ridges.

Explanation of figure 2-1 is as follows:

- When the strongest winds aloft are the westerlies on the western side of the trough, the trough deepens [fig. 2-1, view (A)].
- When the strongest winds aloft are the westerlies at the base of the trough, the trough moves rapidly eastward and does not change in intensity [fig. 2-1, view (B)].
- When the strongest winds are on the east side of the trough, the trough fills [fig. 2-1, view (C)].

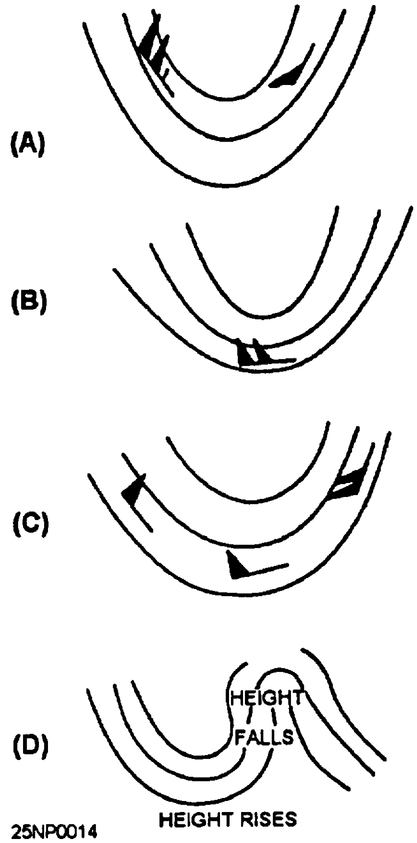

Figure 2-1.-Effect of super gradient winds on the deepening and filling of troughs. (A) Strongest winds on the west side of trough;(B) strongest winds in southern portion of trough; (C) strongest winds on east side of trough; (D) excessive contour gradients.

- Sharply curved ridges with excessive contour gradients are unstable and rotate rapidly clockwise, causing large height rises and filling in the trough area downstream, and large height falls in the left side of the strong gradient ridge [fig. 2-1, view (D)].

Convergence and Divergence Above 500 Millibars

Study the 300-mb (or 200-mb) chart to determine areas of convergence and divergence. Note these areas of convergence and divergence.

Convergence and divergence are covered in chapter 1 of this TRAMAN, and also in the *AG2* TRAMAN, volume 1. As a review of the effects of convergence and divergence, and the changes in intensity of troughs and ridges, we have the following rules:

Refer to chapter 1 for illustrations of these rules.

- Divergence and upper height falls are associated with high-speed winds approaching cyclonically curved weak contour gradients. Divergence results in height falls to the left of the high-speed current.

- Convergence and upper height rises are associated with low-speed winds approaching straight or cyclonically curved strong contour gradients and with high-speed winds approaching anticyclonically curved weak contour gradients.

FORECASTING THE MOVEMENT OF UPPER LEVEL FEATURES

The movement of upper level features is discussed in the following text.

Movement of Highs

Areas of high pressure possess certain characteristics and traits. The following text discusses these indicators for areas of high pressure.

SEMIPERMANENT HIGHS.— The semipermanent, subtropical highs are ordinarily not subject to much day-to-day movement. When a subtropical high begins to move, it will move with the speed and in the direction of the associated long wave ridge. The movement of the long wave ridge has already been discussed. Also, seasonal movement, though slower and over a longer period of time, should be considered. These highs tend to move poleward and intensify in the summer, and move equatorward and decrease in intensity in the winter.

BLOCKS.— Blocks will ordinarily persist in the same geographic location. Movement of blocks will be in the direction of the strongest winds; for example, eastward when the westerlies are strongest, and westward when the easterlies are strongest. The speed of movement of these systems can usually be determined more accurately by extrapolation, Extrapolation should be used in moving the highs under any circumstance, and the results of this extrapolation should be considered along with any other indications.

Some indications of intensity changes that are exhibited by lower tropospheric charts (700-500 hPa) are as follows:

- Intensification will occur with warm air advection on the west side; weakening and decay will occur with cold air advection on the west side; and there is little or no change in the intensity if the isotherms are symmetric with the contours. This low tropospheric advection is not the cause of the intensity change but is only a indicator. The cause is at higher levels; for example, intensification is caused by high-level cold advection and/or mass convergence.

- Under low zonal index situations, a blocking high will normally exist at a northern latitude and will have a pronounced effect on the systems in that area; in general it will slow the movement

- Under high zonal index situations, there is a strong west to east component to the winds, and systems will move rapidly.

Movement of Closed Lows

The semipermanent Icelandic and Aleutian lows undergo little movement. These semipermanent lows will decrease or increase in area of coverage; occasionally split, or elongate east-west during periods of high zonal index. North-south displacements are due primarily to seasonal effects. The movement of these semipermanent lows is derived primarily from extrapolation.

EXTRAPOLATION.— Extrapolation can be used at times to forecast both the movement and the intensity of upper closed lows. This method should be used in conjunction with other methods to arrive at the predicted position and intensity. Figure 2-2 shows some examples of simple extrapolation of both movement and intensity. Remember, there are many variations to these patterns, and each case must be treated individually.

Figure 2-2, view (A), illustrates a forecast in which a low is assumed to be moving at a constant rate and filling. Since the low has moved 300 nautical miles in the past 24 hours, it maybe assumed that it will move 300 nautical miles in the next 24-hour period. Similarly, since the central height value has increased by 30 meters in the past 24 hours, you would forecast the same 30 meter increase for the next 24 hours. While this procedure is very simple, it is seldom sufficiently accurate. It is often refined by consulting a sequence of upper air data to determine a rate of change.

This principle is illustrated in figure 2-2, view (B). By consulting the previous charts, we find the low is filling at a rate of 30 meters per 24 hours; therefore, this constant rate is predicted to continue for the next 24 hours. However, the rate of movement is decreasing at a constant rate of change of 100 nautical miles in 24 hours. Hence, this constant rate of change of movement is then assumed to continue for the next 24 hours, so the low is now predicted to move just 200 nautical miles in the next 24 hours.

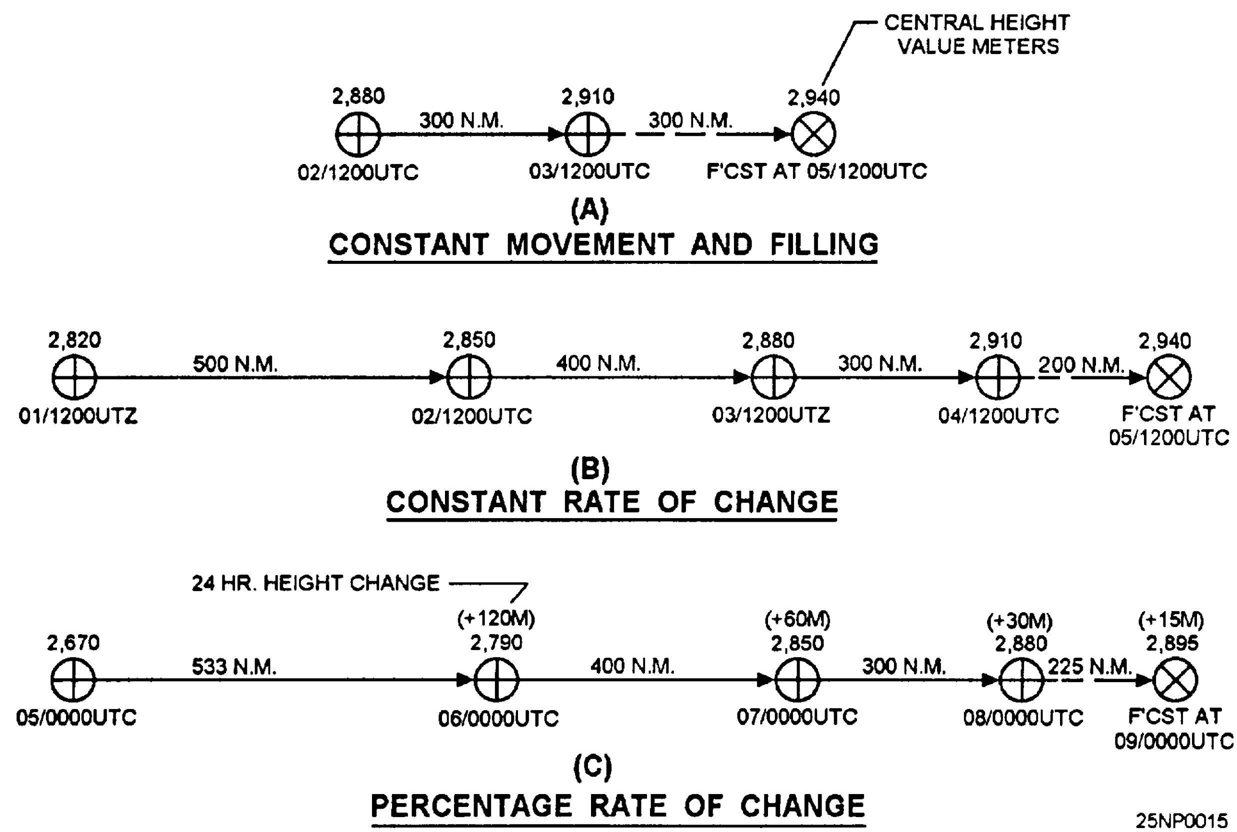

Figure 2-2.-Simple extrapolation of the movement and Intensity of a closed low on the 700-mb chart. (A) Constant movement and filling (B) constant rate of change, (C) percentage rate of change.

Frequently neither of these two situations exist, and both the change in movement and the height center change occur at a proportional rate. This is illustrated in figure 2-2, view (C). From a sequence of charts 24 hours apart, it is shown that the low is filling at a decreasing rate and also moving at a decreasing rate. The height change value is 50 percent of the value 24 hours previously on the successive charts, and the rate of movement is 75 percent. We then assume this constant percentage rate to continue for the next 24 hours, so the low is forecast to move 225 nautical miles and fill only 15 meters.

Accelerations may be handled in a similar manner as the decelerations shown in figure 2-2. Also, a sequence of 12-hour charts could be used in lieu of 24-hour charts to determine past trends.

CRITICAL ECCENTRICITY.— When a migratory system is unusually intense, the system may extend vertically beyond the 300-hPa level. Advection considerations, contour-isotherm relationships, convergence and divergence considerations, and the location of the jet max will yield the movement vector. These principles are applied in the same manner as when the movement of long waves are determined. The eccentricity formula may be applied to derive a movement vector, but only when a nearly straight eastward or westward movement is apparent. Migratory lows also follow the steering principle and the mean climatological tracks. The climatological tracks must be used cautiously for the obvious reasons. The rise and fall centers of the time differential charts are of great aid in determining an extrapolated movement vector, and extrapolation is the primary method by which the movement of a closed low is determined.

Certain cutoff lows and migratory dynamic cold lows lend themselves to movement calculation by the eccentricity formula. The conditions under which this formula may be applied are:

- The low must have one or more closed contours (nearly circular in shape).

- The strongest winds must be directly north or south of the center. The location of the max winds determines the direction of movement. When the strongest winds are the easterlies north of the low, the low moves westward; when the strongest winds are the westerlies south of the low, the low will move eastward. The low will also move toward the weakest diverging cyclonic gradient and parallel to the strongest current. Systems moving eastward must have a greater speed in order to overcome convergence upstream-there is normally convergence east of a low system.

The eccentricity formula is written:

$$Ec = V - V' - 2C$$

or

$$2C = V - V' - EC$$

where

Ec is the critical eccentricity y value.

V is the wind speed south of the closed low.

V′ is the wind speed north of the closed low.

C is the speed of the closed low (in knots).

To obtain the value of C, it is necessary to determine the latitude of the center of the low and the spread (in degrees latitude) between the strongest winds in the low and the center of the low. Apply these values to table 2-1 to determine the tabular value. Apply the tabular value to the critical eccentricity formula to obtain 2C, thus C. In determining the critical eccentricity of a system, it is necessary to interpolate both for latitude and the spread. A negative value for C indicates westward movement; a positive value indicates eastward movement.

LOCATION OF THE JET STREAM.— As long as a jet maximum is situated, or moves to the western side of a low, this low will not move. When the jet center has rounded the southern periphery of the low, and is not followed by another center upstream, the low will move rapidly and fill.

Table 2-1.-Critical Eccentricity Value

Latitude (degrees)	Spread (degrees latitude)				
	1°	3°	5°	10°	20°
80	.1	.9	2.5	--	--
70	.2	1.8	4.9	19.5	80.0
60	.3	2.6	7.1	27.0	115.0
50	.4	3.3	9.1	37.0	150.0
40	.4	4.0	10.9	43.5	175.0
30	.5	4.5	12.3	50.0	200.0
20	.5	4.9	13.3	53.0	--
10	.6	5.2	14.0	56.0	--

ISOTHERM-CONTOUR RELATIONSHIP.— Little movement will occur if the isotherms and contours are symmetrical (no advection). Lows will intensify and retrogress if cold air advection occurs to the west and fill and progress eastward if warm air advection occurs to the west.

FORECASTING THE INTENSITY OF UPPER LEVEL AND ASSOCIATED SURFACE FEATURES

Many of the same considerations used in the movement of closed centers aloft may also apply to forecasting their intensity. Extrapolation and the use of time differentials aid in forecasting the change and magnitude of increases and decreases. Again, rise and fall indications must be used in conjunction with advection considerations, divergence indications, and other previously discussed factors.

Intensity Forecasting Principles (Highs)

The following text discusses how atmospheric conditions affect the forecasted intensity of high pressure systems.

- Highs undergo little or no change in intensity when isotherms and contours are symmetrical

- Highs intensify when warm air advection occurs on the west side of the high.

- Highs weaken when cold air advection occurs on the west side of the high.

- Blocking highs *usually* intensify during westward movement and weaken during eastward movement.

- Convergence and height rises occur in the downstream trough when high-speed winds with a strong gradient approach low-speed winds with an anticyclonic weak gradient. This is often the case in ridges where the west side contains the high-speed winds; the ridge intensifies due to this accumulation of mass. This situation has also been termed *overshooting*. This situation can be detected at the 500-hPa level, but the 300-hPa level is better suited because it is the addition or removal of mass at higher levels that determines the height of the 500-hPa contours.

- Rise and fall centers on the time differential chart indicate the changes in intensity, both sign (increasing, decreasing) and magnitude of change, if any, in decimeters. The magnitude of the height rises or falls can be adjusted if other indications reveal that a slowing down or a speeding up of the processes is occurring, and expected to continue.

Intensity Forecasting Principles (Lows)

The following text discusses how atmospheric conditions affect the forecasted intensity of low-pressure systems.

- Lows and cutoff lows deepen when cold air advection occurs on the west side of the trough.

- Lows fill when warm air advection occurs on the west side of the low.

- Lows fill when a jet maximum rounds the southern periphery of the low.

- Lows fill when the jet maximum is on the east side of the low, if another jet max does not follow.

- Lows deepen when the jet max remains on the west side of the low, provided the jet max to the west of the low is not preceded by another on the southern periphery or eastern periphery of the low, for this indicates no change in intensity.

- The 24-hour rise and fall centers aid in extrapolating both the change and the magnitude of falls in moving lows. Again, these rise and fall indications must be considered along with advection factors, divergence indications, and the indications of the contour-isotherm relationships.

FORECASTING THE FORMATION OF UPPER LEVEL AND ASSOCIATED SURFACE FEATURES

The following text deals with the formation of upper level and associated surface features, and how atmospheric features affect them.

Formation Forecasting Principles (Highs)

The following are atmospheric condition indicators that are relevant to the formation of highs.

- Cold air masses of polar and Arctic origin generally give no indication of the formation of highs at the 500-hPa level or higher, as these airmasses normally do not extend to this level.

- The shallow anticyclones of polar or Arctic origin give indications of their genesis primarily on the surface and the 850-mb charts. The area of genesis will show progressively colder temperatures at the surface and aloft; however, the drop in the 850-mb temperatures does not occur at the same rate as at the surface. This is an indication that a very strong inversion is in the process of forming. The air in the source region must be relatively stagnant.

- High-level anticyclogenesis is indicated when low-level warm air advection is accompanied by stratospheric cold air advection. This situation has primary application to the formation of blocks, as high-level anticyclogenesis is primarily associated with the formation of blocks and the intensification of the ridges of the subtropical highs.

- Blocks should normally be forecast to form only over the eastern portion of the oceans in the middle and high latitudes. Warm air is normally present to the north and northwest.

Formation Forecasting Principles (Lows)

There are certain conditions required in the atmosphere, as well as certain atmospheric indicators, for cyclogenesis to occur. The greater the number of these indicators/conditions in agreement, the greater the success in forecasting cyclogenesis. Some of them are listed below:

- An area of divergence exists aloft.

- A jet maximum on the west side of a low indicates deepening and southward movement.

- Cold air advection in the lower troposphere and warming in the lower stratosphere is associated with the formation of or deepening of lows.

Formation Forecasting Principles (Cutoff Lows)

Another task in forecasting is that of the formation of cutoff lows. Some of the indicators are as follows:

- They generally form only off the southwestern coast of the United States and the northwestern coast of Africa.

- The upstream ridge intensifies greatly. This intensifying upstream ridge contains an increasing, strong, southwesterly flow.

- Strong northerlies on the west side of the trough.

- Height falls move south or southeastward.

- Strong cold air advection occurs on the west side of the upper trough.

Constructing Upper Level Prognostic Charts

The constant pressure prognostic chart is about to take form. The forecasted position of the long wave troughs and ridges have been determined and depicted on the tentative prognostic chart. The position of the highs, lows, and cutoff centers were then determined and depicted on the tentative prognostic chart. Short waves were treated in a similar fashion. Contours are then depicted. The height values of the contours are determined by actual changes in intensity of the systems. The pattern of the contours is largely determined by the position of the long waves, short waves, and closed pressure systems. Contours are drawn in accordance with the following eight steps:

1. Outline the areas of warm and cold advection in the stratum between 500 and 200 hPa, and move the thickness lines at approximately 50 percent of the indicated thickness gradient in the direction of the thermal wind.

2. Tentatively note, at several points on the chart, the areas of height changes on the constant pressure surface above the existing height values.

3. Move the areas of 24-hour height rises and falls at the speed of the short waves, and note at several key points the amount and direction of the height change from the current chart.

4. Adjust the advected height changes, and, in turn, adjust these for positions of the long waves, pressure systems, and short waves.

5. Extrapolate heights for selected points at 500 hPa on the basis of the 24-hour time differential indications and advection considerations, provided that they are justified by the indications of high-level convergence and divergence. When the contributions from advection and time differentials are not in agreement with convergence and divergence, adjust the contribution of each and use accordingly.

6. Adjust the height values to the forecasted intensities of the systems. These adjustments can lead to the following:

    - All factors point toward intensification (deepening of lows and filling of highs).

    - One factor washes away the contribution made by another, and the system remains at or near its present state of intensity.

- All factors point toward weakening of the system.

7. Sketch the preliminary contours, connecting the forecast positions of the long waves, short waves, and the pressure systems with the values determined by steps 1 through 5 above.

8. The last step in the construction of a constant pressure prognostic chart is to check the chart for the following points:

- The chart should follow continuity from the existing pattern.

- The chart should be vertically consistent and rational in the horizontal.

- The chart should not deviate from the seasonal pattern unless substantiated beyond a doubt.

- Unless indicators dictate otherwise, it should follow the normal patterns.

Now draw the smooth contours, troughs, ridges, highs, and lows; and adjust the gradients.

Application of Satellite Imagery

Satellite imagery provides the forecaster with information that may be used in conjunction with previously discussed techniques in forecasting movement and intensity of troughs, ridges, and systems aloft. As discussed in the *AG2* TRAMAN, volume 1, satellite imagery should be compared with the analyzed charts and products to ensure they reflect a true picture of the atmosphere. As with the analyses, satellite imagery should also be used in preparation of your forecast products.

The following features can be useful to the forecaster in producing prognostic upper-air charts:

- Positive vorticity advection maximum (PVA maximum) cloud patterns associated with the upper-air troughs and ridges

- Cloud patters indicative of the wind flow aloft

Computer Products

Upper-level prognostic charts with varying valid times are uploaded to the Naval Oceanographic and Data Distribution System (NODDS) daily. Items included on the charts will vary on an individual basis, with respect to the contours for the particular height, isotachs, and isotherms.

The forecaster may use these charts directly for preparing forecasts, or in conjunction with their own prepared products. A complete listing of charts available with descriptions is found in the Navy *Oceanographic Data Distribution System Products Manual,* FLENUMMETOCCENINST 3147.1.

The Fleet Numerical Meteorology and Oceanography Center prepares a large number of computer products for upper air forecasting. The *Numerical Environmental Products Manual,* volume 3 *(Environmental Products),* FLENUMMETOCCENINST 3145.2, lists available products.

SUMMARY

In this chapter we first discussed general prognostic considerations. The value of an accurate, hand drawn analysis was addressed, along with a discussion of available aids, including computer products and satellite imagery. The majority of this chapter deals with objective forecasting techniques used in the preparation of upper level charts. The first topic discussed was that of forecasting the movement of troughs and ridges, followed by a discussion on forecasting the intensity of troughs and ridges. Lastly, forecasting of the movement, intensity, and the formation of upper level systems and associated features were covered.